ALUMINIUM ALLOY AND EXTRUSION

Extruded matte anodised sections are made in large
quantities for architectural and other use. The aluminium alloys used are
6000 series alloys in the Aluminum Association Register. This invention is
concerned with the compositions of the alloys.

The standard production method involves extruding a billet of
10   the chosen alloy, subjecting the extruded section to an alkaline etch, and
anodising the resulting matte surface. Studies on the effect of composition
on matte etching response have been published and each shows the
importance of microstructural features on surface quality. Typically it has
been demonstrated that constituent particles, dispersoids and ageing
15   precipitates influence the surface evolution and final appearance. The
effects of solid solution content, with the exception of Zn additions, have
largely been ignored.

However, there are three important aspects of the aluminium
extrudate etching process. Firstly, the extrudate surface finish from the
20   press influences the uniformity of appearance, with a good finish requiring
less metal removal to achieve acceptable quality. Secondly, the metal
removal rate controls the amount of effluent that has to be controlled and
disposed of; hence there are significant environmental benefits to reducing
the amount of metal removed for an acceptable finish. Thirdly, the final
25   matte appearance of the extrudate is critical and this means both low gloss
(i.e. low brightness) and uniformity.

The benefit of high Fe content to matte finish has been
recognised for some time and this has traditionally been used by the
aluminium and metal finishing industries. The drawbacks of a high Fe
30   content are: 1) the extrudate surface roughness increases making the

product incompatible with others being produced on the same press where
mill finish is critical and 2) a higher metal removal is needed to attain a
uniform etched finish.

This invention results from the inventors' discovery that
control of the Cu content, and to a lesser degree also the Cr content, of the
alloy can have a beneficial effect. The invention thus provides a population
of billets resulting from more than one cast of metal having a specification
such that every billet has a composition (in wt %):

Constituent	Range	Preferred
Fe	< 0.35	0.16 - 0.35
Si	0.20 - 0.6	0.4 - 0.6
Mn	< 0.10	0.01 - 0.05
Mg	0.25 - 0.9	0.35 - 0.6
Cu	< 0.015	< 0.010
Ti	< 0.10	< 0.05
Cr	< 0.10	< 0.09
Zn	< 0.03	< 0.03

balance Al of commercial purity

A cast is defined as the process of converting a body of
molten metal into a plurality of billets - often several hundred billets - of
solid metal. The body of molten metal has a composition which is
controlled to fall within a predetermined specification and which is generally
given to the purchaser or user of the billet. The specification is maintained
for more than one cast, generally for a whole series of casts. In the
present invention the specification (which is not defined herein) is such that
every billet has a composition within the ranges given above. A population
of billets is an unspecified number, usually at least 50 and generally much
more than 100, of billets resulting from more than one cast, usually a series

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of at least 5 and often more than 100 casts, of metal within the specification. A population according to the invention would not be expected to contain any billet having a composition outside the stated range.

5   Extruded sections are made by extruding billets taken from the population. Preferably the extruded sections are subjected to an alkaline etch and are then anodised. The invention also includes extruded sections so made.

The above alloys are within the 6000 series of the Aluminum 10   Association classification and are related to AA6060 and AA6063 generally used to make extruded matt anodised sections.

Mg and Si combine to form dispersed Mg_2Si particles which contribute to dispersion strengthening of the extruded sections. If Mg or Si concentrations fall below the stated ranges, then extruded sections may 15   not achieve desired mechanical properties in the T5 or T6 temper. When the extruded sections are subjected to alkaline etch, the Mg_2Si particles are preferentially dissolved. To some extent, this is advantageous in enhancing the desired mattening effect. But if the Mg and Si contents are too high, problems may arise with regard to ease of extrusion and surface 20   quality obtainable. In some circumstances it is preferable that the Mg content be in the range 0.35 - 0.45%.

Fe is a preferred constituent of the alloy, partly because it contributes to the desired mattening effect and partly because alloys containing no Fe are much more expensive. When the Fe content is too 25   high, problems arise as discussed above.

Mn is beneficial to the desired etch response and helps to counteract Fe by reducing pitting activity. Zn is notorious for the production of a bright spangled appearance. At high concentrations, Ti can give rise to streaking.

30   The level of Cu is controlled to be less than 0.015%,

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preferably less than 0.010%. As the experimental data below show, higher

levels of Cu have a detrimental effect on matte finish and increase the rate

of metal removal during etching. These very low Cu levels cannot be

consistently achieved without positive and deliberate control over alloy

5   composition.

The level of Cr is kept below 0.10% as is conventional. But

an addition of Cr at a level of 0.03 - 0.09% may be made. As the

experimental data below show, Cr at these levels enhances the matte

response to etching but without increasing the metal removal rate.

10   The balance of the alloy is aluminium of commercial purity.

This will normally be primary Al from a smelter, since it would not be easy

to achieve tight compositional control of secondary Al from scrap. The

invention is concerned with commercial scale production, and not with

laboratory experiments using high purity samples.

15   In performing the invention method, an Al alloy of chosen

composition is cast into a billet which is optionally homogenised and

extruded into a section which is cooled. Homogenising conditions do not

appear to have any material effect on the development of a matte surface.

The extruded section may be cooled in still air or more preferably by forced

20   air cooling or quenching.

The extruded section is preferably aged e.g. to T5 or T6

temper. This may be effected by heating the section at 150 - 200°C for a

time to develop peak strength. A preferred regime is 170 - 185°C for 5-6

hours. Ageing has a material effect on mattness. It is believed that ageing

25   grows Mg_2Si particles and that these dissolve during alkaline etch to give a

matt finish.

The extruded section is subjected to alkaline etching to

develop a matte surface. Mention may be made of two commercially

available etch systems:

30   Long-life etch is mainly used in Europe and North America,

and involves treatment for 5 - 20 minutes with a solution of

     100 g/l NaOH

     100 - 160 g/l Al ion

     30 - 50 g/l sequesterant e.g. Na gluconate or Na heptonate

at 50 - 75°C. This typically results in 100g/m^2 metal removal.

     Recovery etch is mainly used in Japan and Canada, and involves treatment for 1 - 10 minutes with a solution of

     30 g/l NaOH

     50 g/l Al ion

at 50 - 75°C. The weaker etch solution and shorter etch time results in a lower level of metal removal.

     After etching, the extruded section has a matte surface. Although mattness is generally understood as the opposite of glossiness, its measurement is somewhat problematic and does vary substantially depending on the nature of the surface and of the treatment it is subjected to. Mattness may be measured by the test in BS 6161 at 60°. As a rough guideline, an Al surface that has been subjected to a long life etch may be regarded as matte if it has a gloss value below about 100; and an Al surface that has been subjected to a recovery etch may be regarded as matte if it has a gloss value below about 150.

     Then the extruded and etched section is anodised under conditions which may be conventional and which form no part of this invention.

     The ability to control etching response is important to ingot producers, extruders and finishers. The knowledge that two key parameters (Cu and Cr) have such a large influence is surprising. Armed with this knowledge, an ingot producer can control performance downstream when other factors are beyond its control.

     Reference is directed to the accompanying drawings in which:-

Figure 1 is a graph of gloss measurement (BS 6161 at 60°) vs etch time for various alloys.

Figure 2 is a graph of weight loss against etch time for the same alloys.

Figure 3 is a bar chart showing the effect of composition and processing on matte response of various AA 6060 alloys after 12 minutes etch.

Figure 4 is a bar chart showing the effect of composition and processing on weight loss of the same AA 6060 alloys after 12 minutes etch.

Figure 5 is a graph of 60° gloss against weight loss, and shows the effect of alloying additions on the same forced air cooled AA 6060 alloys.

Figure 6 is a graph of 60° gloss against weight loss, showing the effect of chromium level and cooling rate on gloss of the same AA 6060 alloys.

Figure 7 is a graph of gloss against weight loss.

Figure 8 is a graph of gloss against copper content.

Figure 9 is a graph of metal removal rate against copper content.

Figure 10 is a graph of gloss against metal removal rate.

Figure 11 is a bar chart comparing two different alloys under a variety of conditions.

Figure 12 is a bar chart comparing gloss of two different alloys under different conditions.

Figure 13 is a graph showing the effect of ageing practice on gloss and tensile strength.

EXAMPLE 1

A series of alloys has been assessed by laboratory trials using commercial size dc ingot, a small extrusion press and controlled etching practices that simulate long life and recovery type caustic etches.
5 The alloys had the composition (in wt %):-

        Si   0.45%

        Fe   0.25%

        Mg   0.41%

        Zn   0.016%

10   Cr, Cu, Mn, each 0.001% unless stated

        Balance commercial purity Al.

The results are shown in Figures 1 and 2. From a range of alloying conditions, all at 0.08%, the Cu in solid solution was seen to have detrimental effect on matte finish (Figure 1) and to increase the metal
15 removal rate by approximately 30% (Figure 2).

EXAMPLE 2

The alloys used in this study are set out in the Table below. Each alloy was dc cast into an ingot which was homogenised.
20 Homogenisation was at 585°C for two hours, in all cases except where indicated in Figures 3 and 4, where one ingot was homogenised at 530°C for 30 minutes. The homogenised ingots were extruded to form extruded sections which were either still air cooled (1.25°C/s) or forced air cooled (6.5°C/s) and aged for 5 hours at 185°C. The extruded and aged sections
25 were subjected to a long-life etch for 12 minutes at 60°C. The results of this trial are shown in Figures 3 and 4. As can be seen:

      - Homogenisation conditions have very little effect on either gloss or weight loss.

      - Forced air cooling has a minor but beneficial effect on
30 mattness.

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- Cu at 0.03% has a major and detrimental effect, both on mattness (i.e. the etched product was more glossy) and on metal weight loss.

It is not known why the etching behaviour of these alloys is so sensitive to Cu level in solid solution when all previous work has indicated that the main parameters in the microstructure are coarse and fine particles. It is not envisaged that the Cu will play a part in the formation of dispersoids or ageing precipitates and thus must be in solid solution. One clue to the importance of solute elements can be gained from the general observation that the fine scale matrix attack dominates the etched surface.

Sample No.	Alloy Composition %						
	Si	Fe	Cu	Mn	Mg	Cr	Ti
1	.45	.21	.001	.002	.41	<.001	.011
2	.30	.19	.001	.002	.42	<.001	0.14
3	.60	.20	.001	.002	,42	.001	.007
4	.45	.20	.001	.071	.41	.001	.011
5	.43	.20	.030	.002	.40	.001	.011
6	.45	.20	.001	.002	.40	.050	.010
7	.45	.20	.001	.002	.40	.103	.011

Balance Al.

EXAMPLE 3

This example is based on the same trial and the same alloys as Example 2, but focuses on the effect of Cr. Figure 5 shows that an alloy containing 0.05% added chromium gives a lower gloss level for a given metal weight loss in comparison with a base line alloy 6060 with no additional elements. Also included for comparison are the Cu variant, a Mn addition, and an alloy containing 0.10% Cr which does not have the same beneficial effect (samples 5, 4 and 7 in the Table).

The difference between 0.05 and 0.10% Cr is also shown in Figure 6, but in this case the effect of cooling rate after extrusion is also included. These data indicate that process conditions are important and this may well be linked to the precipitation of Mg_2Si on to dispersoids when the cooling rate is too low.

Figure 7 is a graph of gloss against weight loss showing selected data from three of the alloys in the study. The detrimental effect of 0.03% Cu, and the beneficial effect of 0.05% Cr are clearly apparent.

EXAMPLE 4

AA6060 alloy ingots were produced in the laboratory by conventional DC casting with copper contents of 0.001, 0.006, 0.012, 0.016 and 0.03 wt%. The base alloy composition was 0.40 wt% Mg - 0.44 wt% Si - 0.20 wt% Fe - 0.007 wt% Zn. The material was extruded, forced air quenched at the press and aged for 5 hrs @ 185°C. Samples were etched in a long life type etchant for incremental times up to 20 minutes. The gloss values were measured and the samples were weighed to give a value of metal removal rate.

Figure 8 shows the gloss level achieved with a typical metal removal figure of 100 g/m^2 as a function of copper content. The gloss level increases linearly with copper content within and beyond the inventive range. Figure 9 shows the effect of copper content on the metal removal

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rate. The rate increases slightly above 0.001 wt% Cu but then levels off within the defined range before increasing again above 0.016 wt%. The lower metal removal rate associated with 0.015 wt% Cu or less is a useful feature as it means for a given etch time these alloys will undergo less aluminium dissolution and will therefore generate less etch sludge. The same data is presented in Figure 8 as gloss vs. Metal removal. From this figure it is clear that the alloys within the defined range are more efficient in achieving a required gloss level. For example to achieve a gloss level of 80, less metal has to be removed for alloys containing < 0.016 wt% as compared to the alloy containing 0.03 wt%.

EXAMPLE 5

Plant Trial

The following compositions were given identical homogenisation practices and extruded into the same profile:

Control:

- 0.46 wt% Si - 0.20 wt% Fe - 0.04 wt% Cu - 0.39 wt% Mg - 0.02 wt% Zn

Alloy within inventive range:

- 0.46 wt% Si - 0.20 wt% Fe - 0.01 wt% Cu - 0.40 wt% Mg - 0.02 wt% Zn.

Some material was left in the T4 temper and the remainder was aged to the T5 temper (6 hrs @ 185°C). Lengths from both compositions and both tempers were etched and anodised within the same batch. The material was etched for 8 minutes to give a metal removal figure of 104 g/m². Some lengths were anodised to give a 5 micron anodic film. Samples were also given a 15 minute etch in the laboratory to give 130 g/m² metal removal. Figure 11 summarises the gloss results. The low copper version consistently gave a lower gloss finish for both tempers and etches in the as etched and etched plus anodised conditions. These gloss trends corresponded to the visual appearance of the profiles.

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EXAMPLE 6

Plant Trial

Two compositions were processed in this test

Control:

5   0.49 wt% Mg - 0.47 wt% Si - 0.23 wt% Fe - 0.004 wt% Zn - 0.02 wt% Cu

Alloy within inventive range:

0.38 wt% Mg - 0.45 wt% Si - 0.20 wt% Fe - 0.015 wt% Zn - 0.01 wt% Cu

The two billets were extruded into the same profile under

identical conditions and aged to the T6 temper. Figure 12 shows the as

10   etched gloss results obtained. The low copper variant gave a considerably

lower gloss level in spite of the slightly lower Fe content, which is known to

influence the final gloss achieved.

EXAMPLE 7

15   ### Effect of Ageing Practice

Laboratory tests have demonstrated that the final gloss level

achieved is a very strong function of the ageing practice applied to the

alloy. Figure 13 shows the variation in etched gloss with tensile strength

for a number of ageing temperatures. The various tensile strength values

20   represent different heat treatment times at the various temperatures. The

results indicate that the lower gloss values are achieved by ageing to full

strength at 170 or 185°C. The results also explain some of the variability in

the prior art on this subject.

25   ## COMPARATIVE EXAMPLE

Over a two-year period, 1242 casts of a variant of AA6060

were made from virgin smelter metal and recycled scrap. The AA6060

specification calls for a maximum of 0.10% Cu. When the Cu was

controlled within the AA6060 specification, the following variation was

30   found:

Year	Number of Casts	Cu Content	
		% Casts with < 0.010% Cu	% Casts with < 0.015% Cu
1	786	19.2%	44.4%
2	456	16.9%	45.8%

The variation in the Cu level in this population of billets is outside the present invention. Satisfactory extrusion and anodising performance was obtained but because of the variation in Cu level from one cast to another, it was not possible to reduce the amount of metal removed during etching and still obtain a uniform gloss level.

By controlling the purity of the virgin metal and the quality and amount or recycled scrap added to each cast, it is possible according to the invention to reduce the Cu level of all casts below 0.015 or 0.010% Cu to meet a tighter specification within the AA6060 composition.